Outgrowing the Dark Ages: agrarian productivity in Carolingian Europe re-evaluated*

by Jonathan Jarrett

Abstract

Despite numerous studies that stand against it, there remains a textbook consensus that agriculture in the early Middle Ages was unusually low in productive capacity compared to the Roman and high medieval periods. The persistence of this view of early medieval agriculture can in part be explained by the requirement of a progress narrative in medieval economic history but is also attributable to the continuing influence of the work of Georges Duby. Duby's view rested on repeated incorrect or inadequate readings of his source materials, which this article deconstructs. Better figures for early medieval crop yields are available which remove any evidential basis for a belief that early medieval agriculture was poorer in yield than that of later eras. The cliché of low early medieval yields must therefore be abandoned and a different basis for economic development be sought.

A relatively recent textbook of medieval history includes the following two sentences: 'By modern standards, Carolingian crop yields were abysmally low. Today a farmer can expect to reap between twenty-five to thirty berries of grain for every seed planted; a Carolingian farmer could expect from about two to four.'[1] Of course, there is a long historical tradition of viewing the Middle Ages as benighted, primitive and superstitious, so as to show better our modern escape from these conditions. Popular clichés about medieval standards of bathing, childcare, life expectancy, justice and hostility to enquiry abound, circulating on the Internet and in

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[1] Jo Ann Hoeppner Moran Cruz and Richard Gerberding, *Medieval worlds: an introduction to European history, 300–1492* (2004), p. 162.

works of popular history like Manchester's *A world lit only by fire*. The quote just singled out is not such an instance, however; not only was it written by established medievalists, but also, in this textbook, it is specifically the early Middle Ages that are singled out for opprobrium. A few pages later we are told that in the high Middle Ages, 'the yield from fields increased – from a very feeble grain to seed ratio of 1.5 to 2:1 in Carolingian times to 6:1 by the thirteenth century'. Neither is this the only textbook (nor indeed work of academic history) in which this supposed fact can be found.[2]

As an investigation of this instance, but also others, quickly makes clear, the common ancestor of almost all such statements is the work of Georges Duby.[3] While he did not originate the figures quoted, he is the most cited source of them. Moreover, not only was his particular use of them accompanied with supporting evidence from a wider area of Europe than previous usages (i.e. from Italy and England as well as from northern France and the Low Countries); it was also built into a convincing edifice of economic history with considerable explanatory power. His work was quickly and widely translated, in editions that are still in print today. Yet almost as soon as Duby's work had been generally received, rebuttals of it began to emerge, and the consensus among agricultural historians of the areas from which Duby drew his evidence is now very largely that he was wrong.[4] Why then do we still find this cliché repeated for each new generation of students to absorb, and for each new general history of the period written by anyone from outside the field of north-western European agricultural history to accept and incorporate?

This article sets out to address these questions and attempts to deliver a more lethal blow to the Duby case than has hitherto been inflicted. It will be shown in what follows not only why such pessimistic readings of the early medieval evidence have been mistaken, but that better figures either do exist or can be derived from that evidence – not the figures we might wish to have, but figures more accurate than those in circulation, and which allow us to mount a more sensible comparison of early medieval and high medieval agricultural productivity – and

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[2] William Manchester, *A world lit only by fire. The medieval mind and the Renaissance: portrait of an age* (1992); cf. Kathleen Davis, *Periodization and sovereignty: how ideas of feudalism and secularization govern the politics of time* (2008), for a suggestion of why such narratives have been so seductive. Other instances of our non-fact: Robert Fossier, *L'enfance de l'Europe: X–XIIe siècles* (1982), p. 615; Norman Pounds, *An economic history of medieval Europe* (sec. edn, 1994), p. 198; Kathy Lynne Roper Pearson, *Conflicting loyalties in early medieval Bavaria: a view of socio-political interaction, 680–900* (1999), pp. 76–7; Marcel Mazoyer and Laurence Roudart, *A history of world agriculture: from the neolithic age to the current crisis* (2006), p. 281 and n. 10. The second quote: Moran and Gerberding, *Medieval worlds*, p. 223.

[3] The only relevant work in the bibliography of Moran and Gerberding, *Medieval worlds*, is Georges Duby, *The early growth of the European economy: warriors and peasants from the seventh to the twelfth century*,

trans. Howard B. Clarke (1974); see n. 7 below.

[4] Perhaps the most recent round-up of the literature in this area is Jean-Pierre Devroey and Anne Nissen, 'Early Middle Ages, 500-1000', in Erik Thoen *et al.* (eds), *Struggling with the environment: Land use and productivity* (Rural Economy and Society in North-Western Europe, 500-2000, 4, 2015), pp. 11–68 at pp. 51–5), but for older consensus to the same effect see Yoshiki Morimoto, 'Autour du grand domaine carolingien: aperçu critique de recherches récentes sur l'histoire rurale du haut Moyen Âge (1987–1992)', in Adriaan Verhulst and Y. Morimoto (eds), *Économie rurale et économie urbaine au Moyen Âge. Landwirtschaft und Stadtswirtschaft im Mittelalter* (Publications du Centre belge d'histoire rurale 108, 1994), pp. 25–79, repr. in Morimoto, *Études sur l'économie rurale du haut Moyen Âge: historiographie, régime domanial, polyptyques carolingiens* (Bibliothèque du Moyen Âge, 25, 2008), pp. 81–132 (82–6 of the reprint). Further references are given below.

that this requires historians in general to rethink the overall narrative of Duby's work. It is argued here that not only is there is no adequate basis on which to claim that Carolingian-era agriculture, or early medieval agriculture more generally, was less effective or productive than the agriculture of the periods before or after it, there is an argument to be made that it was as productive or even more so, and thus, to question any narrative of progress based on the transition from low to high yields in the medieval period.

All of this, however, necessarily entails some kind of answer to the question posed above, why the idea of Carolingian agricultural productivity persists, and indeed, given that persistence, why this attempt to undermine it should be any more successful than those hitherto, and it is with these issues that I shall begin.[5]

<p style="text-align:center">I</p>

It is worth beginning with Duby's own words (or at least those into which Howard B. Clarke rendered them), so that the object and its basis are clear in the discussion. In the book known to the English-reading world as *The early growth of the European economy*, we find the following:

> One solitary document provides numerical data on this score: one, moreover, whose interpretation is an extremely delicate matter. This is the survey of the royal manor of Annapes [*sic*]. It contains estimates on the one hand of the amounts of grain still held in store at the time of the inquiry, that is during the winter between the autumn and the spring sowings; and on the other hand of those that had just been sown. A comparison of the two sets of figures shows that, on the main farm, it had been necessary to set aside for the new sowings 54 per cent of the previous spelt harvest, 60 per cent of the wheat, 62 per cent of the barley and the whole of the rye harvest. This is another way of saying that the yields of these four cereal crops for that year had respectively been 1.8, 1.7, 1.6 and lastly 1.0 to 1 – in other words, nil. These ratios are so low that many historians have refused to accept that they could ever have corresponded to reality. But it should be remembered that the year to which these estimates apply had produced a poor harvest, worse at any rate than the preceding year's, for substantial quantities of barley and spelt remained in reserve from that particular harvest. Further, production was slightly higher on the subsidiary farms of the central manor, where the barley yield succeeded in reaching 2.2 to 1. But it is clear from other sources that yields of this order, between 1.6 to 1 and 2.2 to 1, were far from being exceptional in early agriculture … The Lombard monastery of St Giulia of Bréscia [*sic*], which consumed some 6,600 measures of grain annually, would have 9,000 sown to cover its needs, which means that the return normally available to the lord was being estimated at 1.7 to 1. On one manor of the Parisian abbey of St-Germain-des-Prés, where 650 measures of corn had been sown on the lord's fields, threshing services imposed on dependent peasants were fixed in anticipation of a surplus of 400 measures. Here again the expected yield was approximately 1.6 to 1.[6]

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5   This question was posed by an anonymous reviewer of this article; I hope that the following answers it.
6   Duby, *Early growth*, p. 28.

Slightly more detail is given in Duby's earlier and larger *Rural economy and country life in the medieval West*, which is quoted below, but the essential sources of his data are clear here (if unreferenced): the manor of Annappes, in modern-day France, whose stocks of produce were recorded in a text underlying the Carolingian estate survey models known as the *Brevium exempla* at around AD 800; the Italian monastery of Santa Giulia di Brescia, or San Salvatore as it was called when the inventory or polyptych that provided Duby's figures was compiled around 900; and the large monastery of Saint-Germain-des-Prés in modern-day France, whose polyptych was compiled around 820. All of these Duby first deployed together at a conference in Spoleto in 1966 before incorporating them into the two books whence they are cited here.[7]

Of these different sources, Saint-Germain-des-Prés was perhaps the only one which had not previously been used to generate a picture of early medieval agriculture. The Italian source material had been explored by Gino Luzzato, upon whose arithmetic Duby relied in *Rural Economy*, and the Annappes survey had already been exploited, and much disputed, not least by B. H. Slicher van Bath; the latter was also present at the Spoleto conference, and his debate with Duby is published in the conference proceedings.[8] Duby's particular contribution, therefore, was to bring all these together and to make from them a synthesis.

In doing this, he relied not just on this material, but comparative material from the High Middle Ages which he knew better, perhaps better than anyone: yield figures from the commanderies of the Hospitaller Grand Priory of Saint-Gilles, in Provence, from 1338.[9] By the time he wrote his books these could also be supported by figures from English estates, especially those of the bishopric of Winchester, which would emerge in full a few years later.[10] However, whereas these figures were directly recorded medieval data on crop yields, the early figures were not; they were only data from which such yields might be inferred. It is in that process that Duby's own assumptions about the dynamic of medieval history seem to have interfered.

[7] Georges Duby, 'Le problème des techniques agricoles', in *Agricoltura e mondo rurale in Occidente nell'alto medioevo* (Settimane di studio del Centro italiano di studi sull'alto medioevo 13, 1966), pp. 267–84; Duby, *L'économie rurale et la vie des campagnes dans l'occident médiéval (France, Angleterre, Empire, IX–XV siècles)* (1964), trans. Cynthia Postan as *Rural economy and country life in the medieval West* (1968), pp. 25–7 of the translation; Duby, *Guerriers et paysans, VII–XIIe siècle: premier essor de l'économie européenne* (1973), trans. Clarke as Duby, *Early growth*, pp. 25–9 of the translation.

[8] Gino Luzzatto, 'Mutamenti nell'economia agraria italiana dalla caduta dei Carolingi al principio del sec. XI', in Giuseppe Ermini (ed.), *I problemi comuni dell'Europa post-carolingia* (Settimane di studio del Centro italiano di studi sull'alto medioevo 2, 1955), pp. 601–22; B. H. Slicher van Bath, 'Le climat et les récoltes en haut moyen âge' in *Agricoltura*, pp. 399–428. Another important contribution to Duby's use of the Annappes figures was Philip Grierson, 'The identity of the unnamed fiscs in the «Brevium exempla ad describendas res ecclesiasticas et fiscales»', *Revue belge de philologie et d'histoire*, 18 (1939), pp. 437–61, although Duby would arrive at quite different conclusions with respect to cereal yields.

[9] Georges Duby, 'La seigneurie et l'économie paysanne. Alpes du Sud, 1338', *Études rurales*, 2 (1961), pp. 5–36, repr. in Duby, *Hommes et structures du moyen âge* (Le savoir historique, 1, 1973), pp. 167–201; used without reference in Duby, *Rural economy*, pp. 99–101; see now Benoît Beaucage, 'Les Alpes du Sud en 1338. Sur les traces de Georges Duby', in Phillippe Braunstein (ed.), *Georges Duby* (Études rurales, 145–6, 1997), pp. 113–32. Beaucage has edited the documents in question, as Benoît Beaucage (ed.), *Visites générales des commanderies de l'ordre des Hospitaliers dépendantes du grand-prieuré de Saint-Gilles, 1338 (Archives départementales des Bouches-du-Rhône, 56 H 123)* (1982).

[10] See J. Z. Titow, *Winchester yields: a study in medieval agricultural productivity* (1972; sec. edn, 2002).

For those outside the field of agricultural history, Duby is perhaps more famous for work in one or both of two fields, the one being medieval women, marriage and gender, and the other, more relevant here, being the so-called 'feudal transformation', a term and a concept very substantially of his invention.[11] Based on the 1951 publication of his *thèse d'état*, a micro-historical study of the Mâconnais in Burgundy that has provoked a hundred imitators, he had developed the idea that between approximately 980 and 1030, in the wake of the collapse of Carolingian rule in their old territories, public order and the social structure underwent violent and rapid convulsions in which old, 'public' structures of governance and justice collapsed to be replaced for a while by arbitrary rule by violence that was eventually restructured around the personal ties between man and man which Marc Bloch had already delineated as the fundamental features of what he had called 'feudal society' in the 1930s.[12] Duby's 1951 study exposed, as it seemed, the processes by which society passed from Bloch's first to his second 'feudal' age, but he saw much less of the 'feudal' in the former than in the latter.

Few suggestions in medieval history can have provoked a larger agglomeration of argument and dispute than the 'feudal transformation', but what is not always appreciated is how it and Duby's subsequent work on agriculture are tied together.[13] Increasingly convinced that governmental collapse alone could not explain so large a phenomenon, or at least, not explain its delayed but apparently rapid outburst nearly a century after the first substantial breakdown of the Carolingian order, he searched for a greater cause, and in the tradition of the Annales school in which he worked, sought it logically enough in the system that affected most people at once, to wit, the rural economy.[14] (This distinguishes him from Pirenne who had seen the primary driver of early medieval social and economic change as trade and exchange; for Duby, as for some historians before and since, this was simply not a large enough phenomenon to

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[11] For assessments of Duby's importance in these fields, see respectively Amy Livingstone, 'Pour une révision du « mâle » Moyen Âge de Georges Duby', *Clio*, 8 (1998) (journals.openedition.org/clio/318), and F. L. Cheyette, 'Georges Duby's Mâconnais after fifty years: reading it then and now', *J. Medieval Hist.*, 28 (2002), pp. 291–317. Further references in the latter field are given in n. 13 below.

[12] Georges Duby, *La société aux XIe et XIIe siècles dans le région mâconnais* (1971); on its imitators see Thomas N. Bisson, 'La terre et les hommes: A programme fulfilled?', *French Hist.*, 14 (2000), pp. 322–45. The work of Marc Bloch referenced is of course Bloch, *Feudal society*, trans. L. A. Manyon (2 vols, 1961).

[13] The historiography on this theme is too vast to be referenced here, but attempts to review it can be found in Christian Lauranson-Rosaz, 'En France: le débat sur la "mutation féodale". État de la question', *Scienza & Politica*, 26 (2002), pp. 3–24, and François Bougard, 'Genèse et réception du Mâconnais de Georges Duby', in *Bulletin du Centre d'études médiévales d'Auxerre*, Hors-série no. 1 (2008) (journals.openedition.org/

cem/4183). Three other noteworthy points in discussion, the latter two with extensive reference to older historiography, are Guy Bois, *The transformation of the year one thousand: the village of Lournand from Antiquity to feudalism*, trans. Jean Birrell (1992); Thomas N. Bisson, 'Lordship and tenurial dependence in Flanders, Provence and Occitania (1050–1200)', in *Il feaudalisimo nell'alto medioevo* (Settimane di Studio del Centro Italiano di Studi sull'Alto Medioevo 47, 2 vols, 2000), I, pp. 389–439; Stephen D. White, 'Tenth-century courts at Mâcon and the perils of structuralist history: re-reading Burgundian judicial institutions', in Warren C. Brown and Piotr Górecki (eds), *Conflict in medieval Europe: Changing perspectives on society and culture* (2003), pp. 37–68, repr. in White, *Feuding and peace-making in eleventh-century France* (2005), ch. IX.

[14] As had Marc Bloch, whose *Les caractères originaux de l'histore rurale française* (2 vols, Paris, 1931–56), trans. as Bloch, *French Rural History: an essay on its basic characteristics*, trans. Janet Sondheimer (Berkeley, CA, 1966), thus underpins his *Feudal society*.

explain so big a set of changes.[15]) By an expansion of the economy, and increased availability of wealth for both peasants, and therefore also their lords who extracted it from them by increasingly violent means, a privatization or welling-up of localized, territorialized, power could perhaps be explained. This, however, necessarily entailed the acceptance of a progress narrative when it came to agriculture: if the social phenomena that Duby observed were to be explained as consequences of economic growth, it was necessary for the economy to have increased in power and productivity in the period immediately before and during these changes, compared to its state beforehand; an 'agricultural revolution' must have preceded the 'feudal revolution'. The early medieval rural economy was thus necessarily required to have been weaker than the high medieval one for Duby's theories to work.[16]

II

None of this is to go so far as to say that Duby falsified or deliberately misread his early medieval source materials. As said, especially with Annappes, he trod in the footsteps of 50 years' work if not more in making such deductions about their import.[17] He did, however, choose readings of those materials that fitted his overall conception of the Middle Ages, which should not surprise us. Neither, however, should it surprise us that alternative views could also be sustained from those figures, as Duby was well aware (though he rarely said as much). As early as 1977, an article by Raymond Delatouche mounted an excoriating attack on Duby's choice of and use of early medieval evidence, some of whose conclusions I will reiterate below.[18] Since Delatouche wrote, it has become almost orthodoxy in French-language agricultural history that Duby's figures were serious underestimates, albeit for a variety of reasons and to varying degrees. These interpretations will be investigated below, but as will be clear from above, they have apparently not succeeded in displacing Duby's overall view from the less specialized literature on medieval economy and society. A sharp illustration of this situation can be found in the second and third volumes of the *New Cambridge Medieval History*. In the second, covering the centuries of the Carolingian Empire and edited by a specialist in that polity and its works, the contribution on agriculture was provided by the late Adriaan Verhulst, who had also argued with Duby at the 1966 Spoleto conference and whose view was very much that the Carolingian organization of agriculture could produce results that equaled anything from the following period.[19] As he would write in a larger synthetic work in 2002, therefore:

[15] With reference to Henri Pirenne, *Mohammed and Charlemagne*, trans. Bernard Miall (1939), on which see now Bonnie Effros, 'The enduring attraction of the Pirenne Thesis', *Speculum*, 92 (2017), pp. 184–208. The most obvious proponent of the dominance of the agricultural sector of the economy prior to Duby is probably again Bloch, *Feudal society*; his modern-day counterpart would certainly be Chris Wickham, *Framing the Early Middle Ages; Europe and the Mediterranean, 400–800* (2005).

[16] Noted also by Raymond Delatouche, 'Regards sur l'agriculture aux temps carolingiens', *Journal des savants* (1977), pp. 73–100 at p. 84.

[17] For references see Grierson, 'Unnamed Fiscs', and Jean-Pierre Devroey, *Économie rurale et société dans l'Europe franque: VIe–IXe siècles* (2 vols, 2003–), I, pp. 115–17.

[18] Delatouche, 'Regards'.

[19] Adriaan Verhulst, 'Economic organisation', in Rosamond McKitterick (ed.), *The New Cambridge Medieval History* [hereafter *NCMH*], II, *c.700–c.900* (1995), pp. 481–509; Verhulst, 'La genèse du régime domanial classique en France du haut moyen âge' in *Agricoltura*, pp. 135–60, repr. in Verhulst, *Rural and urban aspects of early medieval northwest Europe* (1992), ch. I.

It is now accepted that the very low yield ratios that were calculated by Duby and Slicher van Bath on the basis of the inventory of grain stocks at the royal estates near Lille around 800 (mainly at Annappes), 1:3, 1:1.6, 1:1.3, 1:1.8, 1:2.15 for spelt, wheat, rye, barley and oats respectively, should be increased slightly in order to express real physical gross yields.[20]

The following *NCMH* volume, however, committed to the period in which Duby had located his supposed transformation, has nothing of this, because its contribution on agriculture was instead provided by Robert Fossier, who in 1990 had to admit that he stood alone in his field for his pessimistic view of the early medieval economy compared to the later period.[21] His picture of an underpopulated, underexploited and substantially wild countryside sits very oddly in the volume next to Janet Nelson's lively picture of the inventive power of royal governments of the era; on what, one is left wondering, did such ambitious governments run if the economies off which they drew their operating capital were so close to subsistence?[22] Moreover, for those of us who have read both volumes and the kinds of books with which I began, why has the 'accepted' alternative laid out by Verhulst not been more widely accepted?

Naturally, this question cannot be definitively answered, but four suggestions seem likely enough to be worth making. The first of these is simply the linguistic and national divisions of the scholarship. Almost all the work dismissing Duby's calculations has been in French; even those parts appearing in English have been from French-speaking scholars.[23] This should not, of course, exclude it from worthy consideration, but it is certainly possible to imagine that the voluminous French-language bibliography on such matters is not fully consulted by those writing English-language textbooks, especially if agriculture or the early Middle Ages are not their core interest. Certainly, French-language material is rare in the bibliographies of such works. It is also likely that the minimal translation of work by scholars opposing Duby's interpretation has led to a false appearance of equality in the debate: as said, Fossier acknowledgedly stands alone among his peers in the field with his negative views, even Duby having relented somewhat towards the end of his life, but with only Verhulst in English to oppose Fossier, and Duby's older works continuing to be reprinted, it is perhaps understandable that the true state of the discussion is not apparent outside the specialist, French-language, field.[24]

A second likelihood is that an attack on Duby's reading of Annappes is not by itself sufficient to convince new readers that he was wrong, because as noted he also provided supporting figures from elsewhere. In fact, Delatouche performed a complete and convincing demonstration of the inadequacy of the materials from Saint-Germain-des-Prés to support such deductions, but precisely because of the definitive nature of that critique, it is not usually repeated by more

[20] Adriaan Verhulst, *The Carolingian economy* (2002), p. 64.

[21] Robert Fossier, 'Rural economy and country life', in Timothy Reuter (ed.), *NCMH,* III, *c.900–c.1024* (1999), pp. 27–63; Georges Duby *et al.*, 'Table ronde', in *La croissance agricole du haut moyen âge: Chronologie, modalités, géographie* (Flaran 10, 1988), pp. 181–203, at pp. 182–4.

[22] Janet L. Nelson, 'Rulers and Government', in Reuter (ed.), *NCMH,* III, pp. 95–129.

[23] See nn. 4, 19 & 20 for references to such work, including Devroey and Nissen, 'Early Middle Ages', which collects most recent references in other languages.

[24] For Fossier's acknowledgement see Duby *et al.*, 'Table ronde', pp. 182–4. Duby's partial retraction came in Georges Duby, *L'histoire continue* (1991), p. 97.

modern work, which engages instead primarily with Annappes.[25] Meanwhile, on the Italian side, as will be shown below, work by Vito Fumagalli quickly rendered obsolete Luzzatto's and Duby's deductions from the Brescia polyptych, which were in any case questionable.[26] But no work that I have found from the French school uses the Italian work, and neither does the Italian work reference the French debate, perhaps not least because in Italy the debate was so quickly closed. So for the reader of either one of these literatures but not the other, Duby's work appears still to have some foundation.

Thirdly, and perhaps most perniciously, Duby's work provided numbers, whereas almost all critique of him has been understandably reluctant to do so.[27] The methodological reasons for this are sound: as will be shown below, Duby's numbers are hopelessly lacking in foundation, and should form the basis of no calculations whatever. Nevertheless, since voluminous quantities of usable numbers do exist from the high medieval period, to provide no numbers at all for the earlier period gives those who would use quantitative data to compare the two eras no basis on which to do so, except by reverting to Duby's.[28] One may note that even Verhulst, as quoted above, while arguing that they should not be accepted, still reproduced Duby's numbers deduced from Annappes, saying only that they should be 'increased slightly'. No cliometrician can follow this instruction: how much is 'slightly'?[29] And this refusal to attempt figures can be found throughout the French scholarship, while the two exceptions, Delatouche and Derville, never made the basis of their alternative calculations clear.[30] Whatever was wrong with Duby's figures, they are observable in his texts and his arithmetic with them was correct. Culpably, perhaps, but inevitably, comparisons therefore continue to be mounted on the basis of them, the only numbers available.

[25] Delatouche, 'Regards', p. 76. Likewise, Werner Rösener, *Agrarwirtschaft, Agrarverfassung und ländliche Gesellschaft im Mittelalter* (Enzyklopädie deutscher Geschichte, 13, 1992), pp. 56–7, Alain Derville, *L'agriculture du nord au Moyen Age: Artois, Cambresis, Flandre Wallonne* (1999), pp. 26–33, Verhulst, *Economy*, p. 64, Devroey, *Économie*, I, pp. 115–17, and Devroey and Nissen, 'Early Middle Ages', p. 51, all say that the debate over cereal yields can only be settled by the Annappes material, before concluding that in fact it cannot.

[26] Vito Fumagalli, 'Rapporto fra grano seminato e grano raccolto nel politico del monastero di S. Tommaso di Reggio' [Report on grain sown and grain harvested in the polyptych of the monastery of Saint Thomas of Reggio], *Rivista di storia dell'agricoltura* 6 (1966), pp. 360–2.

[27] As Morimoto, 'Grand domaine', p. 84 of the reprint, put it, 'L'attitude actuelle commune est de ne plus essayer, à partir des mentions peu nombreuses et délicate d'interprétation, de conjecturer numériquement ce taux, tout en admettant que l'agriculture carolingienne était beaucoup plus productive que certains médiévistes ne l'avaient pensé'; cf. Derville, *L'agriculture*, p. 33: 'Alors, que faire ? Avouer que les chiffres fameux sont inutilisables'; Verhulst, *Economy*, p. 64, quoted above;

and Devroey and Nissen, 'Early Middle Ages', pp. 51–3, which also refuses to attempt figures from the Annappes data but considers no other figures to exist.

[28] For a guide to the survival of high medieval evidence see Bruce M. S. Campbell and David Hardy, 'The Data', in *Three Centuries of English Crop Yields, 1211–1491* (www.cropyields.ac.uk/project.php, accessed 20 Mar. 2019)

[29] Verhulst's only reference here was to Pierre Toubert, 'La part du grand domaine dans le décollage économique de l'Occident (VIIIe – Xe siècles)', in *La croissance agricole*, pp. 53–87, where only p. 67 addresses yields and offers no more than a similar feeling that things must have been better than the figures suggest. The same problem applies with Morimoto's, 'beaucoup plus productive' (see n. 27 above); is 'beaucoup plus' more than 'slightly'? Was this disagreement with Verhulst, or just unquantifiable assumption on both parts?

[30] Delatouche, 'Regards', pp. 76–80, with comparanda gathered from Tsarist Russia as readily as elsewhere in Francia, but also from other places not specified; Derville, *L'agriculture*, pp. 34–6, 'correcting' the figures with data from 1800, thus ineluctably creating a false impression of continuity throughout the period (pp. 36–8).

Lastly and perhaps most powerfully, Duby's overall argument still appeals to those trying to give a picture of the whole of medieval society's development over time. To demean the early Middle Ages in favour of the high and later Middle Ages and later periods is not by any means novel: one does not have to go far back in scholarly time to find the early Middle Ages being described in terms that, whether the exact words are used or not, clearly recall the term 'Dark Ages', with other words like 'barbarian', 'rude', 'primitive' or even 'savage' floating nearby.[31] The political and cultural formations that succeeded Rome were always likely to struggle in the analysis of scholars raised in a culture in which the Classics were the mark of a cultured and educated man and whose artistic, built and even monetary visual cultures were saturated with Roman imagery.[32] In the last 40 or 50 years great strides have been made in combating such prejudices and allowing the early Middle Ages to stand on their own terms. If at times the recognition of the achievement of early medieval figures such as Charlemagne, King Alfred of the West Saxons or Emperor Otto I, to name but a few, or Emperors Justinian I or Basil II in the still-Roman world, has tended simply to replace one set of heroes with another, at least from such a tipping of the balance, equilibrium may yet be hoped for.[33]

If it has not yet arrived, however, this is not least because medieval history does, in most of the terms about which Western modernity cares, present a progress narrative. After the collapse of Roman government in Western Europe and the Mediterranean, cities either disappeared or struggled to maintain their existence; the state-run systems of extraction and the activities that they funded largely ceased or else shrank considerably; the economic basis of almost all polities shifted, and population seems really to have contracted considerably. Then, in the centuries after the year 1000 (if not before), cities, commerce and collective representation before government all became considerably more common, and population apparently grew hand over fist at least until the early fourteenth century.[34] Duby's thesis appears to cohere with the overall dynamic of medieval history and even to offer an explanation for it, and those who undermine his work have so far been unable to replace it. As long as there is an overall sense that the centuries around 1200 were wealthier, more culturally developed and populous than those around 700, an explanatory gap is likely to exist that Duby's picture of agricultural development can fill, and for those tasked with the delineation of the whole of medieval history it will be difficult to manage without it.

It is probably impossible for this last factor to be overcome by a single article. Nonetheless, on all the other counts it appears that there is a need for a study that is able to draw both on French

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[31] See now Janet L. Nelson, 'The Dark Ages', *Hist. Workshop J.*, 63 (2007), pp. 191–201; more widely, Stephen J. Harris and Bryon L. Grigsby (eds), *Misconceptions about the Middle Ages* (2008).

[32] See Peter Bondanella, *The eternal city: Roman images in the modern world* (1987) and Jonathan Jarrett, *Inheriting Rome* (2015), esp. p. 4; also Richard Hingley, *Roman officers and English gentlemen: the imperial origins of Roman archaeology* (2000), esp. pp. 1–37.

[33] Works on Charlemagne are prolific but Alessandro Barbero, *Charlemagne: father of a continent* (2004) exemplifies the laudatory trend; for similar work on

the others named see David Pratt, *The political thought of Alfred the Great* (2006), David S. Bachrach, 'Exercise of royal power in early medieval Europe: the case of Otto the Great, 936–73', *Early Medieval Europe* 17 (2009), pp. 389–419; John Moorhead, *Justinian* (1994); and Catherine Holmes, *Basil II and the governance of empire (976–1025)* (2005). Many important women could also be listed: see as just one example Pauline Stafford, *Queen Emma and Queen Edith: queenship and women's power in eleventh-century England* (1997).

[34] For economic versions of this narrative see Pounds, *Economic history*, or Rösener, *Agrarwirtschaft*, pp. 3–31.

and Italian literature, that is able and willing to demonstrate the mathematical and historical inadequacy of Duby's figures by more than just assertion, and that is willing to put forward alternative, better-founded figures as at least a better basis for comparative calculation. It is probably also helpful that such an article should appear in English, and indeed in a publication which is willing to make it openly available online. This is what this article aims to be. If by indicating why Duby's figures cannot be used and by offering better ones which contradict the expectation that early medieval crop yields were poorer than high medieval ones, it then follows that the progress narrative of medieval history must seek an alternative basis, then perhaps even the fourth obstacle to such an understanding will at least be challenged.

<div style="text-align:center">III</div>

In what follows, I proceed in the following manner. Firstly, Duby's use of each of his key sources is analysed and discussed, with a view in each case either to correcting or salvaging his calculations or showing why this cannot be done. Secondly, a rapid survey of the basis for the figures for yields from before and after the early Middle Ages is offered, as a means of understanding what the requirements of any comparison must be. Thirdly, the few possibilities for deriving usefully comparable figures from the early Middle Ages, not all of which were known to Duby, are set out. Finally, I draw the already-promised conclusions. To begin with, therefore, we must look at Duby's key source, the figures from the royal manor of Annappes.

(a) The Annappes survey in the Brevium exempla

As Delatouche observed, while Duby had other figures too, it was Annappes which provided the key to his argument.[35] These figures are contained within a piece of Carolingian adminis-trative literature whose full title is the *Brevium exempla ad describendas res ecclesiasticas et fiscales*, 'Exemplars of summaries for describing ecclesiastical and fiscal properties'. It is preserved in a single manuscript along with the better-known text we call the *Capitulare de villis*, 'Capitulary on Estates', and the two have reasonably been taken to constitute part of the same project of royal estate management, even though neither survive in any context which might be called official.[36] The actual *Exempla* are four in number, the first three being, respectively, part of a survey of the estates of the monastery of Staffelsee, a fragment of an unidentified text, a list of donors and dependents of the abbey of Wissembourg, and then

[35] Delatouche, 'Regards', pp. 75–6: 'Annapes figure en bonne place dans toutes les histoires économiques, tous les recueils de documents, tous les livres de vulgarisa-tion', with citations in support. Duby was neither the first, nor claimed to be the first, to use these figures. Grierson, 'Unnamed fiscs', pp. 452–61, gives references to older studies.

[36] The edition of reference is now Carl-Richard Bruhl (ed.), *Capitulare de villis: cod. guelf. 254 Helmst. der Herzog August Bibliothek Wolfenbüttel* (Dokumente zur deutschen Geschichte in Faksimiles. Reihe 1: Mittel-lalter, 1 Stuttgart 1971). The *Capitulare* is translated in

H. R. Loyn and John Percival (eds), *The reign of Char-lemagne: documents on Carolingian government and administration* (1975), pp. 64–73, and the *Exempla* ibid., pp. 98–105. On the context and purpose of these texts see now Darryl Campbell, 'The *Capitulare de villis*, the *Brevium exempla*, and the Carolingian court at Aachen', *Early medieval Europe*, 18 (2010), pp. 243–64, and references there but especially Wolfgang Metz, *Das karolingische Reichsgut: eine verfassungs- und ver-waltungsgeschichtliche Untersuchung* (1960), pp. 11–90, which fits the texts into a much wider context of Caro-lingian surveying and administration.

the returns from estate surveys of five fiscal estates, in one of which Annappes was identified in 1895.[37] These texts have all been abbreviated and turned into templates, including phrases such as, 'This is how you should record the rest'.[38] We are lucky, therefore, that any real detail remains in the text, but the details that do include the figures for grain found at Annappes, including that which was already set aside for sowing. The Latin original follows Table 1; the text in translation reads as follows:

Of farm produce: old spelt from last year, 90 *corbes* which can be made into 450 weights of flour; and 100 *modii* of barley. From the present year, 110 *corbes* of spelt, of which 60 *corbes* had been planted, but the rest we found; 100 *modii* of wheat, 60 sown, the rest we found; 98 *modii* of rye all sown; 1,800 *modii* of barley, 1,100 sown, the rest we found; 430 *modii* of oats; one *modius* of beans; 12 *modius* of peas. At five mills were found 800 *modii* of the lesser measure. At four breweries, 650 *modii* of the lesser measure, 240 given to the prebendaries, the rest we found.

At two bridges, 60 *modii* of salt and 2 *denarii*. At four gardens, 11 *denarii*. Also honey, 3 *modii*; about 1 *modius* of butter; bacon, from last year 10 flitches; new flitches, 200, with cuttings and fats; cheese from the present year, 43 weights.

Of livestock: 51 head of larger cattle; five three-year olds; seven two-year olds; seven yearlings; ten two-year old colts; eight yearlings; three stallions; 16 cows; two asses; 50 cows with calves; 20 young bulls; 38 yearling calves; three bulls; 260 hogs; 100 pigs; five boars; 150 sheep with lambs; 200 yearling lambs; 120 rams; 30 goats with kids; 30 yearling kids; three male goats; 30 geese; 80 chickens; 22 peacocks.[39]

The cereal figures can be tabulated as in Table 1.

The reader will note that the idea that certain amounts of the crops in the barns had already been sown rests on the expansion of an abbreviation, *per* Bruhl '*semin*avit', but the facsimile provided in Bruhl's edition (where see fos 10v–11r) makes it clear that the scribe used only a horizontal line to indicate all his or her abbreviations, so that expansion is a matter of guesswork. A perfect tense seems unlikely, however; how could seed already in the ground have been counted? This must instead have been grain stored for seed, which would need to be kept separately anyway.[40] This all therefore seems, superficially, to justify Duby's arithmetic.

[37] Théodore Leuridan, 'Une revendication: Annappes et Gruson sous Charlemagne', *Memoires de la Société des sciences, de l'agriculture et des arts de Lille*, 4ᵉ sèrie, 21 (1895), pp. 133–50, cit. by Grierson, 'Unnamed fiscs' p. 439 n. 2). Duby knew Grierson's article and gave the credit for the identification to him, but did not follow his conclusions (or his spelling).

[38] *Brevium exempla*, c. 23: '*sic cetera breviare debes*'.

[39] For the Latin, from Bruhl as per n. 36 above, see the note to Table 1. This translation is the author's modification of that in Fredric Austin Ogg (ed.), *A source book of mediaeval history: Documents illustrative of European life and institutions from the German invasions* to the Renaissance (1972; first edn. 1907), pp. 127–9, revised by Jerome S. Arkenberg as 'Medieval Sourcebook: Asnapium: An inventory of one of Charlemagne's estates, *c*.800', in Paul Halsall (ed.), *Internet Medieval Sourcebook* (sourcebooks.fordham.edu/halsall/source/800Asnapium.asp).

[40] I owe this last point to Allan Scott McKinley, but see also Peter Reynolds, 'Mediaeval cereal yields in Catalonia and England: an empirical challenge', *Acta Historica et archaeological mediaevalia* 18 (1997), pp. 495–507, repr. as 'Comparative cereal yields from Catalonia and Britain: the result of experimental probability trials', in Immaculada Ollich, Montserrat Rocafiguera and Maria

T A B L E 1. Grain and legumes in store at Annappes in the *Brevium exempla*

	Old crop remaining	New crop remaining	Of which seed
Barley	100 modii	1800 modii	1100 modii
Spelt	90 corbes	110 corbes	60 corbes
Corn	–	100 modii	60 modii
Rye	–	98 modii	'totidem'
Oats	–	430 modii	–
Fava beans	–	1 modius	–
Peas	–	12 modii	–

Note 1.

The text of the section concerned here, as given by Bruhl pp. 52–3, is as follows (with expanded abbreviations in Roman): *Invenimus in Asnapio fisco dominico salam regalem ex lapide facta*m *optime, cameras III, solariis totam casam circu*mdata*m, c*um *pisilib*us *XI, infra cellarium I, porticus II, alias casas infra curte*m *ex ligno factas XVII, cu*m *totidem cameris et ceteris appendiciis bene conpositis; stabolum I, coquina*m *I, pistrinum I, spicaria II, scuras III. Curtem tunimo strenue munitam cum porta lapidea et desuper solarium ad dispensandum. Curticulum simili*te*r tunimo interclausam ordinabiliter dispositam diversi*qu*e gener*is *plantata*m *arborum. Vestimenta: lectum parandum I, drappos ad discum I parandum; toaclam I. Utensilia: concas æreas II, poculares II, calderas æreas II, ferrea I, sartaginem I, gramalium I, andeda*m *I, faru*m *I, secures II, dolatoriam I, terebros II, asciam I, scalpru*m *I, runcina*m *I, plana*m *I, falces II, falciculas II, palas ferro paratas II. Utensilia lignea ad ministrandum sufficien*te*r. De conlaboratu: spelta vetus de anno pr*æ*terito corbe*s *XC, quae possunt fieri de farina pensas CCCCL. Ordeum modios C. Presenti anno fuer*un*t spelt*ae corbe*s *CX: seminavit ex ipsis corbe*s *LX, reliq*ua *rep*perimus *frum*e*nti *mod*ii *C: semina*vit *LX, reliq*ua *rep*perimus; sigil*is *mod*ios XCVIII semina*vit *totide*m; ordeo *mod*ios mil*le *DCCC: seminavit I C; reliq*ua *rep*perimus. Avena *mod*ios CCCCXXX, faba *mod*ium I, pisos *mod*ios XII. De mol*inis V: *mod*ios DCCC ad minorem mensuram; ded*it *prebendar*iis *mod*ios CCXL; reliq*ua *rep*perimus. De camb*is IIII: *mod*ios DCL ad minorem mensura*m. De pont*ibus II: sale *mod*ios LX et sol*idos II. De ortis IIII: sol*idos XI; mel *mod*ios III. De censu: butyrum *mod*ium I; lartum de pr*æterito ann*o baccon*es X, novis baccon*es CC cu*m *minucia et unct*is; format*icos de anno pres*enti pensas XLIII. De peculo: iument*a maior*a capit*a LI, de ann*o tertio V, de pret*erito VII, de pres*enti VII; poledros bimos X, annotin*os VIII, emissarios III, bov*es XVI, asinos II, vaccas cum vitulis L, iuvencos XX, vitul*os annotin*os XXXVIII, taur*os III, porcos maior*es CCLX, porcell*os CC, arietes CXX, capras cum *h*ed*is XXX, hed*os annotin*os XXX, hirc*os III, auc*as XXX, pull*os LXXX, pavon*es XXII.*

Note 2.

A *corbis* seems to have been a eighth of a *modius*: see Jean-Pierre Devroey, 'Units of measurement in the early medieval economy: the example of Carolingian food rations', *French Hist.* 1 (1987), pp. 68–92.

Many authors have found the results too low to be feasible: Jean-Pierre Devroey, in summarizing scholarly responses, returns to Delatouche's words: 'an agriculture where the normal yields were 1.6 for 1 is physically impossible: it would not produce the energy necessary for its practice'.[41] That is not inherently true, but certainly if these figures were what Duby

Note 40 *continued*
Ocaña (eds), *Experimentació arqueològica sobre conreus medievals a l'Esquerda, 1991–1994* [Archaeological experimentation on medieval crop-growing at l'Esquerda, 1991–94] (Monografies d'arqueològia medieval i postmedieval, 3, Barcelona 1998), pp. 121–8

(p. 497 of the original).
[41] Devroey, *Économie rurale*, p. 116 and n. 97. Delatouche, 'Regards', p. 77: 'Une agriculture dont le rendement normal serait de 1,6/1 est physiquement impossible: elle ne produirait pas l'énergie nécessaire à sa poursuite'.

represented them to be, then less than two-fifths of any given harvest would have been available as food, the rest needing to be resown to ensure such a return next year, and this amply justifies Duby's rhetorical question, 'Could output really have been at so derisory a level?' although of course he concluded that it could.[42]

Various attempts have been made to make the Annappes figures more acceptable. The most obvious disclaimer, because as Duby said it is clear from the figures, is that Annappes had had a bad year compared to the one before. Campbell's recent analysis of the *Brevium exempla* in conjunction with the *Capitulare de villis* suggests that the most plausible context for the two texts is in the settling of Charlemagne's government at Aachen, with the consequent need to rearrange the fiscal supply system.[43] Of course, the *Exempla* may not have been modified from immediately current texts. If they were, however, and if Campbell is right and the pairing of the two texts then dates from 794, the immediately preceding years had indeed both been years of famine. This is not a small modification, as it implies that even in one such year things could be markedly better than the other for which we have detailed figures; but there is no way to be sure that the *Exempla*'s sources did in fact come from so close to the compilation date, if Campbell has that right (of which we cannot be certain).

Devroey has collated other attempts to make sense of the Annappes figures.[44] Sigaut suggested that the labourers' pay had already been taken out of this harvest before it was stored, estimating that the figures should therefore be raised by 8–15 per cent; Comet argues that the tithe would already have been taken out, meaning that yields should be increased by nearly 10 per cent; and Slicher van Bath thought that the sowing figures should be counted as additional to the harvest, of which Duby observed, not unreasonably, 'Slicher van Bath does not seem to correctly interpret the figures in the text'.[45] As Verhulst had previously noted, with a similar tabulation of different opinions, the resultant possible error margin is a full 100 per cent of the original figures.[46] Rösener has subsequently defended Slicher van Bath's argument, but without actually addressing the fact that, as the reader can see, the text does not mean what he thought.[47]

Rösener has, indeed, gone on to propose revised crop yields figures typical for the early and high middle ages, of 3:1 and 5:1–7:1 respectively, thus leaving the progress narrative intact, but he does not make the basis for these new figures clear.[48] On investigation, they transpire to be

[42] Duby, *Rural economy*, p. 26.

[43] Campbell, '*Capitulare*', anticipated by Delatouche, 'Regards', p. 77.

[44] Devroey, *Économie*, pp. 115–17; see also Delatouche, 'Regards', to which could be added non-French work such as Grierson, 'Unnamed fiscs', pp. 453–7, esp. 453 nn. 2–4 for references to previous work by Dopsch, Baist, Halphen and Lot, and Janet Nelson, *Charles the Bald* (1992), p. 27, where in fact I found the suggestion that inspired this article.

[45] Devroey cites François Sigaut, 'L'évolution technique des agricultures européennes avant l'époque industrielle', *Revue archéologique du Centre de la France*, 27 (1988), pp. 7–41; Georges Comet, *Le paysan et son outil : Essai d'histoire technique des céréales (France, VIIIᵉ–XVᵉ siècle)* (Collection de l'École française de Rome, 165, 1992), pp. 302–3; and Slicher van Bath, 'Le climat', to which last cf. Duby, *Rural economy*, p. 26 n. 42, whence the quote.

[46] Verhulst, *Economy*, p. 64.

[47] Rösener, *Agrarwirtschaft*, pp. 56–7.

[48] Werner Rösener, 'L'histoire rurale de l'Europe médiévale et l'apport de Georges Duby', trans. Philippe Braunstein, in Braunstein, *Duby*, pp. 91–102, citing only Rösener, *Agrarwirtschaft*, p. 75, where the early medieval figures are not discussed. Rösener's argument is not made clearer by the fact that *Agrarwirtschaft* has a bibliography but no notes, so that one must often deduce his source.

no more than Slicher van Bath's figures for the early period, repeated and contrasted to what seems to be a mean calculated from, on the one hand, Jan Titow's averages of thousands of high medieval yield figures from the estates of Winchester bishopric, and on the other hand two unusually high yields reported by none other than Duby, even though Rösener claims to be revising Duby's work and even though Duby himself made it clear that the figures were double or treble the usual value recorded in the age.[49] Clearly, as Duby himself knew, two single outlier figures should not be allowed to modify an average whose basis is thousands of data larger, and none of Rösener's figures should be used.[50]

Duby later admitted that criticism of his understanding of yields was fair, but stopped short of saying how it should be revised.[51] Devroey instead argues that the yield figures may be taken as accurate, but related only to the demesne part of the estate, which could have provided the required crops despite such low productivity simply by being large, while the peasant tenants whose labour farmed it would have got better results from their own land, partly out of the dedication born of dire need, but also because of better access to manure from the animals which they probably owned.[52] He also emphasizes that such crops as the fisc was interested in, and were therefore recorded in the *Exempla*, were only part of a much larger complex of available foodstuffs.[53] Certainly, there were far more elements to Carolingian agriculture than grand demesne grain yields, but while this is obviously true and if these other arguments were true too, the situation might look quite different, the figures presented by Duby, and others before and since, do not even need this cushioning; they are inaccurate in their own terms.

Duby wrote, when rhetorically questioning these data:

> The text, however, is categorical. It prevents us from assuming that, apart from seed corn, grain had already been taken away between harvest time and the visit of the compilers of the inventory for domestic consumption or for despatch outside the estate.[54]

But the text makes no such assertion, and indeed if one reads further into it, it is evident that that was exactly what had happened: the very next sentence tells us that there was also a substantial amount of grain at the five mills on the estate, waiting to be ground. It says: 'from the five mills: 80 *modios* of the lesser measure; there had been 240 *modios* given to the *prebendarii*, the rest we found.'[55] The "lesser measure" employed here was probably three

[49] Ibid., pp. 55–6 and 75, with reference to what must be Titow, *Winchester yields* and to Duby, *Rural economy*, p. 100, albeit in its German translation.

[50] Ibid., pp. 99–103, sees Duby arguing that these figures were unrepresentative, and ending with a suggested typical high medieval figure of 4:1. Note that by p. 103 his suggested figure for normal early medieval crop yields had also somehow become 2.5:1, rather than the lower figure he had deduced from Annappes.

[51] Duby, *L'histoire continue*, p. 97.

[52] Devroey, *Économie*, pp. 115–24, following Delatouche, 'Regards', pp. 91–4. Note, though, that manuring some soils annually can actually decrease yield: see Reynolds, 'Yields', p. 499.

[53] Devroey, *Économie*, pp. 102–8, repeated in Devroey and Nissen, 'Early Middle Ages', pp. 54–5; cf. Peter J. Reynolds and Christine E. Shaw, 'The third harvest of the first millennium A.D. in the Plana de Vic', in Immaculada Ollich i Castanyer (ed.), *Actes del Congrés Internacional Gerbert d'Orlhac i el seu temps: Catalunya i Europa a la fi del 1r mil·lenni, Vic-Ripoll, 10–13 de Novembre de 1999* [Acts of the International Congress 'Gerbert of Aurillac and his times: Catalonia and Europe at the end of the first millennium'] (Vic, 1999), pp. 339–51.

[54] Duby, *Rural economy*, p. 26.

[55] *Brevium exempla*, p. 53; for the Latin the note to Table 1 above.

quarters the size of the full Carolingian modius, which means, at its most basic, that as well as what was in the barns, 300 *modii* overall, of we know not what crop, had already been extracted from the estate total to be ground, and some of it already distributed to those who were supported by the estate. This latter is worth the emphasis of repetition: the source tells us that the crop had already been partly distributed before the surveyors got there. Additionally, there were another '650 *modii* of the lesser measure' counted at the four malting-kilns, which would be equivalent to 488 full *modii* by our current understanding.[56] Again, we cannot know how much more there had been before this distribution had been made, but even this increases the total seed recorded by a third, doubles the amount still available as food and raises the overall yield figure from Annappes, as Duby could have calculated it, to 2.02:1 or thereabouts.[57]

In fact, Duby should have made no such calculation, because of the nature of the Annappes estate, which is to say, it was a fiscal complex. Its purpose was, therefore, as Campbell has recently usefully reminded us, to generate produce for the court, either for its direct sustenance or, in the case of produce which could not be easily transported over whatever the relevant distance was that year, to be sold to the court's profit. The official whom the *Capitulare* envisages in charge of each such estate was supposed, as Campbell puts it, 'to ensure the timely transportation and accurate inventorying of estates' revenues – food, money and craft goods – to the Carolingian court', and then 'to store any leftover goods pending further royal instructions'.[58] There is little sign that the court ever visited Annappes, and the nearest known *palatium*, Samoussy near Laon, was also a rare stopping-place.[59] Some of this produce may have been transported the 250 km or so to the relatively new court centre at Aachen, but we might imagine the primary consumers of the royal renders here as royal officials, messengers and so on, rather than the court fully assembled. Annappes's stores may also have served to supply the local army when raised or, especially at this time, alleviate famine.[60] This all relies on information outwith the actual text, but that an inventory was indeed taken implies some such thinking at the court.

It is therefore only the 'leftover goods' that would have been on site to be counted by the surveyors. In other words, Duby's figures are not for the crop as it came off the field, but for the reserve, the surplus available after the owners' share of the proceeds, and everything that might have been spared for the estate's tenants and labourers had been removed. This was what was left in case, as the *Capitulare* seems to envisage, the court should briefly turn up to its estate here and need to be fed, or in case famine relief needed to be organized using fiscal resources.[61] For

[56] Ibid.; for the metrology, see Jean-Pierre Devroey, 'Units of measurement in the early medieval economy: the example of Carolingian food rations', *French Hist.* 1 (1987), pp. 68–92.

[57] Counting all grains together but not the legumes, reckoning *corbes* as an eighth of a *modius*, and the lesser *modius* as three-quarters of the full one, as per Devroey, 'Units', p. 71, and rounding the results to two decimal places, so:

$$((100 + 90/8) + 1800 + (110/8) + 100 + 98 + 430) /$$
$$(1100 + 60 + 60 + 98) =$$
$$2553.00 / 1265.50 = 2.02.$$

[58] Campbell, '*Capitulare*', pp. 244–8, with citations of the text; quotes here from pp. 245 and 246. This perceptive reading of the text does not, however, prevent him quoting its figures as 'grain yields' in his Table 1 (p. 253).

[59] On Samoussy see Ross Samson, 'The residences of Potentiores in Gaul and Germania in the fifth to mid-ninth centuries' (unpublished PhD thesis, University of Glasgow, 1991), pp. 299–301.

[60] On famine relief see n. 61 below.

[61] Cf. Delatouche, 'Regards', p. 76. See Campbell, '*Capitulare*', p. 246, for the needs of the court; on

this reason, no doubt, there were also 210 flitches of bacon and 43 *pensas* of cheese in store at Annappes, as well as a considerable number of live beasts still on the estate. But these, like the grain, were leftovers. There would, after all, be no point in inventorying for a court report goods that were due to be consumed locally; by the time the court might need them they could all have been gone. What was recorded for the court would have been surplus in the purest sense, and thus cannot provide a foundation for the actual subsistence levels of the estate to which that surplus was by definition additional. We cannot therefore know what the crop yields at Annappes had been in whatever year the survey was conducted; all we can say, *pace* Duby and his predecessors, is that they had been at least 2.0:1 and presumably rather more.

(b) Yields at Santa Giulia di Brescia

Duby's second example, the Italian monastery of Santa Giulia di Brescia, was not recording a reserve in this fashion. An inventory of the monastery's lands survives as 12 sheets of parchment stitched together in a roll in the Archivio di Stato di Milano.[62] The roll appears to be deficient at both ends: in particular, although the text opens with lands around Brescia, the monastery itself is not covered, meaning that what is now the first parchment was probably not so originally. We do not know how much has been lost. The date comes from a dorsal note that may have been based on the now-lost head of the document, but it has struck most commentators as a reasonable fit to the three scripts involved in writing the document, at least two of whose writers shared responsibility for copying within entries and so were clearly working together from written data which they had before them. The format in which they recorded this information included running totals that make it possible to do checksums on their addition, and these usually work out correctly. While there is much that could be said about the implications of these facts for the operations of an early tenth-century administration, here we must confine ourselves to the belief that its information is likely to be contemporary and more or less consistent.

Now, in *The growth of the European economy*, as we have said above, Duby wrote of this document's information: 'The Lombard monastery of St Giulia of Bréscia [*sic*], which consumed some 6,600 measures of grain annually, would have 9,000 sown to cover its needs, which means that the return normally available to the lord was being estimated at 1.7 to 1'.[63] He gave no more detail here, but in the earlier *Rural economy* he had supplied more and different figures:

> We must not, of course, generalize from one set of figures obtained from a single source. But it is possible to find elsewhere some other traces of output, somewhat higher than that which can be derived from the Annapes [*sic*] inventory, but even so representing a low yield

Note 61 *continued*
stockpiling for famine see Jean-Pierre Devroey, 'La céréaliculture dans le monde franc', in *L'ambiente vegetale nell'alto medioevo* (Settimane di studio del Centro italiano di studi sull'alto medioevo, 37, 1990), pp. 221–56 (at pp. 247–8).
   [62] Gianfranco Pasquali (ed.), 'S. Giulia di Brescia' [St Julia of Brescia], in Andrea Castagnetti *et al.* (eds),

Inventari altomedievali di terre, coloni e redditi [Early medieval inventories of lands, serfs and renders] (Fonti per la storia d'Italia, 104, 1979), pp. 41–94, also printed in Ezio Barbieri *et al.* (eds), *Le carte del monastero di S. Giulia di Brescia* [The charters of the monastery of St Julia of Brescia] (2008), I, no. 46. The details that follow are from Pasquali's introduction, pp. 43–52.
   [63] Duby, *Early growth*, p. 28.

and a derisory rate of profit when compared with the value of the capital in land and seed corn. One significant fact is that compilers who visited the farms of the abbey of St Giulia of Brescia [*sic*] in 905–906 to compile a polyptych found there reserves of grain in the barns which were barely higher and sometimes lower than the quantity needed for sowing. Thus at Prozano [*sic* for Porzano] where the fields could take 300 *muids* of seed corn, the stocks in the estate barn amounted to only 360 *muids* of which 140 were of millet. At Canella 90 *muids* were needed for sowing and 51 were in the barns; at Temulina 32 and 37.[64]

Again, the mathematics seems superficially justifiable, but only if all the input figures are indeed what is here represented. To check this, it is easiest to take an exemplary estate from the polyptych and work its figures through as Duby would have had to read them:

> In the *curtis* of Mairano, 2 houses, 3 hearths, arable land for the sowing of 150 *modia*, vine for 35 *amphorae*, meadows for 20 cartloads, wood for fattening 100 pigs; 1 mill, whence 12 *modia* of grain come per year; 9 *prebendarii* within the *curtis*, male and female together; 5 *modia* of corn, 52 *modia* of rye, 6 *modia* of oats, 1 *modium* of legumes, 70 *modia* of millet; that is, 133 *modia*; 24 *amphorae* of wine, 3 oxen, 35 pigs, 12 sheep, 4 goats, 7 geese, 20 chickens; cheese, 12 pounds of wool; and there are 7 lots, on which reside 11 slaves; each one of them does 4 days work in the week; and there are 11 other lots, on which reside 11 free men; 8 of them do 3 days work in the week, and 3 of them do 2 days work in the week and render 15 *denarii* in silver; and there are 3 lots, on which reside 3 tenants, who render the third *modium* of grain, half the wine and 5 ploughshares; 1 vacant lot, whence come 6 *modia* of grain and 2 *amphorae* of wine a year.[65]

Here again the basis for calculations like Duby's is perfectly clear. The estate had a capacity for 150 *modia* to be sown; they had in store only 133, giving a disastrous ratio of 0.9:1 if the next year's crop had not yet been sown, and only 1.22:1 even if it had. Applying these assumptions across the polyptych gave Duby the global figures for Santa Giulia's sowing and harvest that he used in 1964. Nonetheless, those calculations rested on a number of silent assumptions, whose exposure dangerously weakens their validity.

The first of these assumptions is the most sustainable, which is that the 22 devolved allotments (the seven held by slaves, the 11 freemen's and the four others) were not themselves included in the estate's count of available arable. Since the occupants of these lots were keeping between two-thirds and, apparently, all of what they grew, and the size of their respective portions is unguessable, including their lands in the estate's size would make it impossible to know on how much of the estate the stored crop would have been sown. There are several cases elsewhere in the polyptych, however, where the tenants rendered more wine than the estate could reportedly have delivered, and so on, so it seems likely that the allotments were indeed excluded from the basic measurement of the estate.[66] Unfortunately this is only the first assumption.

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64   Duby, *Rural economy*, p. 26.
65   Pasquali, 'S. Giulia', p. 69, my translation. I follow the usage of the source in considering *modium* a neuter noun for its purposes.

66   For example, a *curtis* probably outside the city of Brescia had vine good for five *amphorae* but its tenants rendered nine (ibid., pp. 58–9).

The second assumption behind the arithmetic of low yields here is that the grain found needs to have been the whole harvest, perhaps less the crop sown for next year. We do not, however, know how close to the harvest these figures were collected. Consequently, we cannot discount the possibility observed at Annappes, that a portion of the harvest had already been consumed when the surveyors took their count. If not, indeed, what had anyone on the estate had been eating since the harvest? This is all the more serious a concern because there were two obvious drains on the crop here, the first being the paid workers, the *prebendarii*, whom this crop had to feed, and the second being the monastery to whose ultimate benefit this estate was being managed. Since presumably neither the workers nor the monks were allowed to starve, without knowing how much was allotted for their consumption or how long after harvest this enumeration was made we cannot possibly guess the amount that had actually come from the fields.

Duby's arithmetic also required that the size of the arable accounted to the estate was all in use for growing at once.[67] If, for some reason, the estate was not running at full capacity and its farmers were sowing only 100 *modia*, then Duby's results would have to be improved by a third. The estate's count of wine shows, however, that this must be considered, because the same logic can be applied to it: the vines could produce 33 *amphorae* but there were only 24 in store. The first figure here is not planting seed, however, as with the grain: grapes do not need to be put back in the ground to ensure next year's vintage. If these vineyards were inventoried that year as being able to produce 33 *amphorae* despite there being only 24 *amphorae* to show this, either the estate was not in fact growing everything it could produce, or else some of what it did had already been shipped out or consumed. The counts in the polyptych do not, therefore, tell us how much of each estate's possible crop was actually being cultivated.

In any case, if the estates were to remain productive, it would of course have been necessary to leave some of the arable of any estate fallow each year. Its full capacity would therefore never have been in use.[68] Although we do not know what system of rotation was in use on Santa Giulia's estates, or even that it was the same throughout, some of each estate's land must have been left unsown each year to ensure continuing fertility. This might be as much as a half, effectively doubling the yield figures by halving the amount of grain sown, but was probably at least a third, which still makes a considerable difference.[69] By this point, one can see that

[67] Also noted by Delatouche, 'Regards', p. 78, although I cannot explain his substitute figures.

[68] Grierson, 'Unnamed fiscs', pp. 452–4, criticized others for omitting this factor from their calculations; Duby knew this article, and indeed wrote about fallowing immediately before his discussion of crop yields in *Rural economy* (pp. 22–5), but nevertheless committed exactly the same mistake.

[69] There is an extensive literature on systems of field rotation in the early Middle Ages, as the spread of triennial rotation was (and is) one of the technical improvements that Duby and others saw behind the increase in cereal yields they placed in the High Middle Ages: see Duby, *Rural economy*, pp. 90–9 and

Duby, 'La révolution agricole médiévale', *Revue de géographie de Lyon*, 29 (1954), pp. 361–6, reprinted as 'Discussion: La révolution agricole médiévale', ed. Philippe Braunstein, in Braunstein, *Duby*, pp. 51–7. In fact, it has become clear (and already was to Duby: see *Rural economy*, pp. 96–9) that practice was extremely varied and that the transition was by no means necessarily from biennial to triennial rotation even if these were common choices. See, of many possible citations, Benoît Beaucage, 'Les Alpes du sud en 1338 : sur les traces de Georges Duby', in Braunstein, *Duby*, pp. 113–32 (pp. 127–31 with refs); Matthieu Arnoux, 'Paysage avec culture et animaux: variations autour du thème des pratiques agraires', ibid. pp. 133–44 (esp. 134–41);

no sensible scholar should accord this arithmetic any basis at all. Duby's figures represent not even a minimum, but a compounded set of errors that the actual crop yields here must have exceeded by an unknowably large margin.

(c) The Figures from Saint-Germain-des-Prés

For the sake of completeness, one should also address the figures that Duby provided from the inventory compiled for Abbot Irminon of Saint-Germain-des-Prés in the early ninth century, quoted above. There, an estate at Maisons-sur-Seine good for 650 *modii* demanded the threshing of only 408 *modii* from its tenants, having therefore, Duby presumed, produced no more than that and the seed-corn for next year.[70] Some of what has been said above can immediately be repeated in this case too: the farmers at Maisons would never have sown a full 650 *modii* due to the need for fallow, there is no allowance here for any deductions, and so on. It is also clear that there could be other means of threshing grain above this limit which are not recorded here. In fact, Maisons is the only estate in the entire polypytch of Irminon where threshing is even mentioned, so unless every other estate went hungry other means must have been found, such as doing this task as part of the day-work that most of the abbey's tenants are recorded as owing, including at Maisons.[71]

In any case, on closer inspection the text signally fails to support Duby's arithmetic. It does indeed say that the estate was good for 650 *modii* of grain to be sown, and it does indeed say that the first tenants listed, Cristingaudus and his wife Amaltrudis, held a free manse and as part of the dues they owed from it threshed 12 *modii* of corn in the demesne granary every year.[72] But there were not 34 manses doing such service, as Duby claimed; there are manses equivalent to a number of 24½. Furthermore, in the text only Cristingaudus

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Note 69 *continued*

Yoshiki Morimoto, 'L'assolement triennial au haut Moyen Âge: une analyse des données des polyptyques carolingiennes', in Verhulst and Morimoto, *Économie rurale*, pp. 91–125, repr. in Morimoto, *Études*, pp. 347–79; Maria Ocaña i Subirana, *El món agrari i els cicles agrícoles a la Catalunya vella (s. IX–XIII)* [The agrarian world and agricultural cycles in Old Catalonia (ninth to thirteenth centuries)] (Documenta, 1, Barcelona, 1998), pp. 67–9; Verhulst, *Economy*, pp. 61–4; Devroey, *Économie*, pp. 108–11; and Devroey and Nissen, 'Early Middle Ages', pp. 41–4, of which the essential common ground is that practice was varied, and had been for a long time. Cf. for more dogmatic views, Helmut Hildebrandt, 'Systems of agriculture in Central Europe up to the tenth and eleventh centuries', in Della Hooke (ed.), *Anglo-Saxon settlements* (1988), pp. 275–90; Rösener, *Agrarwirtschaft*, pp. 19–20; Joachim Henning, 'Did the "Agricultural Revolution" go east with Carolingian conquest? Some reflections on early medieval rural economics of the Baiuvarii and Thuringi', in Janine Fries-Knoblach and Heiko Steuer (eds), *The Baiuvarii and Thuringi: an ethnographic perspective* (Studies in

Historical Archaeoethnology, 9, 2014), pp. 331–59; and indeed Grierson, 'Unnamed fiscs', p. 456.

[70] Duby, *Rural economy*, p. 27, citing (n. 44) Benjamin Guérard (ed.), *Polyptyque de l'abbé Irminon, ou Dénombrement des manses, des serfs et des revenus de l'abbaye de Saint-Germain-des-Prés sous le règne de Charlemagne* (2 vols in 3, 1844), II, pp. 271–2 (*recte* II, pp. 271–7, no. XXV). In the more careful edition of Auguste Longnon (ed.), *Polyptyque de l'abbaye de Saint-Germain des Prés rédigé au temps de l'Abbé Irminon* (2 vols in 3, Paris, 1886–95), this is II, pp. 353–5.

[71] Longnon, *Polyptyque*, XXV.19 or XXV.24, for tenants doing *anecinga* or week-work; cf. Yoshiki Morimoto, 'In ebdomada operatur, quicquit precipitur ei (Le polyptyque de Prüm, X): service arbitraire ou service hebdomadaire? Une contribution à l'étude de la corvée au haut Moyen Âge', in Jean-Marie Duvosquel and Erik Thoen (eds), *Peasants and townsmen in the Middle Ages:* studia in honorem *Adriaan Verhulst* (Gand, 1995), pp. 347–72, repr. in Morimoto, *Études*, pp. 380–98, for what might be included in week-work.

[72] Longnon, *Polyptyque*, XXV.1 and XXV.3 respectively.

and Amaltrudis are explicitly tasked with threshing; the next tenant, Airoardus, admittedly 'pays similarly' (from a rather smaller holding), but the one after that, Gautsarius, with a wife Godaltrudis, and children who like all those in the text had space left for their names that was never filled in, answered for half a manse only, and the next tenants, Sichelm and Landa, 'pay similarly' even though they held a full manse.[73] Never again in the text, in fact, is it explicitly said that a manse in Maisons answered at the full rate rather than the half, and in some cases it is not actually said that they paid anything.[74] Duby's assumption that all manses had threshing to do at the lord's granary seems dangerously unfounded; only an aggregate equivalent to nine manses in fact manifestly did so. There were probably other sources of labour for threshing that would have accounted for more grain but on the other hand hardly any of the people whom Duby thought threshed seem actually to have been required to do so. It is equally likely, of course, that the scribe was simply very careless with such details, as he certainly was with others, but this also does nothing for the accuracy of Duby's deduction.

All of this, however, becomes irrelevant, in the face of Delatouche's trenchant observation that Maisons is the very last estate enumerated in a polyptych that is incomplete: the count of the tenants breaks off in the course of listing the area's forty-second household.[75] We do not know how many more there were, but the previous area surveyed had contained 178, so it could have been many.[76] This, of course, makes it impossible to guess what kind of labour supply the demesne managers at Maisons really had at their disposal or how much grain it would have been wrought upon, and deductions based upon it cannot be considered evidential. Duby should not have tried to produce them.

Although Duby by no means held the monopoly on bad deductions from early medieval agricultural data, the widespread publication of his figures and the extent to which they have been reproduced justify this extended demonstration of their frailty.[77] This helps explain the widespread consensus in French scholarship that no useful figures can be given for early medieval agricultural productivity, and that we must be content with the assumption that it

[73] Ibid., XXV.4–6.

[74] Ibid., XXV.14, XXV.38, XXV.39, XXV.41 and XXV.42 record no renders from the tenants concerned; XXV.23 expressly states that no more is done than specified, which does not include threshing.

[75] Delatouche, 'Regards', p. 76.

[76] Longnon, *Polyptyque*, II, pp. 317–52 (no. XXIV).

[77] Worse horrors may be observed in Manuel Riu i Riu, 'Pesos, mides i mesures a la Catalunya del segle XIII: aportació al seu estudi' [Weights and measures in thirteenth-century Catalonia: a step towards their study], *Anuario de estudios medievales* [Annual of medieval studies], 26 (1996), pp. 825–36, repr. without bibliography as 'Pesos, mides i mesures a la Catalunya medieval: aportació al seu estudi' [Weights and measures in medieval Catalonia: a step towards their study] in Ollich *et al.*, *Experimentació*, pp. 77–82, which says at p. 831 of the original:

Pensem que Ramon d'Abadal, en examinar la documentació del monestir de Cuixà pertanyent al segle IX, establí que el modi era la una mesura de volum del gra necessari per a sembrar la mujada (*modiata*) de terra o sigui, aproximadament, mitja hectàrea (un xic menys) i que s'aproximaria a un pes de 80 kgs., amb un rendiment aproximat de 500 kgs. per mujada (uns 1.050 kgs. per hectàrea).

$500 \div 80 = 6.25$, but the analysis in question, Ramon d'Abadal i de Vinyals, 'Com neix i creix un gran monestir pirinenc abans de l'any mil: Eixalada-Cuixà' [How a great Pyrenean monastery was born and grew before the year 1000: Eixalada-Cuxa], *Analecta montserratensia* [Montserrat analects], 8 (1954), pp. 125–337, repr. *separatim* (Montserrat, 1954) doc. no. 54 with the relevant section of analysis pp. 160–61 and n. 99 of the original and p. 42 and n. 99 of the monographic reprint, offers no such foundation. Among many figures

was sufficient for the activities of the age.[78] Yet our sources contain the possibility of better figures, though these also require caution lest they in turn assume a vigour they cannot sustain. From here, therefore, I briefly survey comparative figures for crop yields from before and after the early Middle Ages and consider the implications of modern archaeological experimentation in this arena, before returning to the polyptych of Santa Giulia di Brescia and another Italian source of similar date that Duby did not use and demonstrating that we do, in fact, have usable figures for early medieval crop yields which exceed Duby's pessimistic levels by a small but significant margin.

<p style="text-align:center">IV</p>

Little space can be given here to the figures of other periods, not least as these have conventionally been employed as a contrast to the purported figures for early medieval production that we have now demolished. It is, however, worth giving at least an idea of what they are. For the Roman period we have no direct administrative records and have to rely on the personal writings of landowners as to what return they expected on crops sown on their estates: Cicero expected eight- to ten-fold yields from his lands in Sicily, whereas a century later the would-be agronomist Columella forecast yields of only 4:1 from cornfields in central Italy.[79] This has been read as evidence for the decline of productivity in Roman agriculture in the period and linked to changes in labour structures but it is very evident that like is not necessarily here being compared with like and that, in any case, the real substance of the Empire's agriculture lay by the time of Columella in Africa and Egypt, and anyone farming cereals in Italy was unlikely to be doing so as a cash crop.[80] There is little more information than this with which to compare, but it is worth noting that while these figures are clearly in excess of Duby's early medieval ones, they do not necessarily represent any great increase or decrease compared to the more accurate yields that can be deduced even from the evidence that Duby used, as shown above; their minima fall only slightly below Columella's figures.

Note 77 *continued*

that Abadal imported from unspecified modern ethnological observation were in fact the yields he assumed the estate in question should have had, making Riu's use of them as if they were medieval data especially perverse. As Abadal himself noted, p. 161, n. 99, 'Cap d'aquestes bases no pot ésser refermada en dades concretes documentals de l'època ….', although this did not prevent him trying to supply them.

[78] See n. 27 above, to which one can add Devroey, 'Céréaliculture', p. 244, with reference to other equally sceptical work, not least Delatouche, 'Regards', who of course tried anyway.

[79] Kenneth D. White, 'The efficiency of Roman farming under the Empire', *Ag. Hist.*, 30 (1956), pp. 85–9 at p. 88. It should be noted that Roman agricultural history has also lately become somewhat more agnostic

about the realism of such figures: see Alan Bowman and Andrew Wilson, 'Introduction: quantifying Roman agriculture' in Bowman and Wilson (eds), *The Roman agricultural economy: organization, investment, and production* (2013), pp 1–32.

[80] White, 'Efficiency', p. 88; cf. Paul Erdkamp, *The grain market in the Roman Empire: a social, political and economic study* (2005), pp. 35–54, which posits yields of 8:1 in Sicily and even higher in Egypt. By the sixth century Palestine was thought to be good for yields of between 5:1 and 7:1, and Egypt rather more; see Cécile Morrisson and Jean-Pierre Sodini, 'The sixth-century economy', trans. by Charles Dibble, in Angeliki E. Laiou (ed.), *The economic history of Byzantium from the seventh through the fifteenth Century* (3 vols, 2002), I, pp. 171–220 at p. 196.

Much better information exists from the high medieval period. Duby's use of a highly informative survey from the Provençal Hospitaller priory at Saint-Gilles, which includes contemporary yield figures from many of its estates, has already been mentioned. This document was a goldmine for Duby's earliest work, but even the most fertile estates in it did not render more than 6:1, and 4:1 was much more usual; some especially unprofitable lands only managed 2:1.[81] But comparison with other information makes clear the plausibility of these figures, this being especially possible now due to the recent collection and publication online of perhaps 75 per cent of all available crop yield information from high medieval Britain by Bruce M. S. Campbell, amounting to an incredible 30,000 records from 1211 to 1491, with a principal concentration between 1272 to 1431. Half of the information comes from the widespread lands of the Bishop of Winchester.[82] To summarize this mass of data in a few sentences is both mean and difficult, not least since the open publication of it does not use absolute numbers but a graph calculated from a statistical baseline, but within these terms it seems fair to say that the yields observed in their documentation fall on average between 2.7:1 and 3.9:1, even if occasional figures as high as 10:1 are recorded in an English context and even higher elsewhere.[83] At this rate, neither ancient nor high medieval cereal production seems so very different to the early medieval situation as Duby could have recorded it.

V

A very different picture however comes from the world of experimental archaeology. Since the 1970s, following the initial success of work done at the Butser Iron Age Farm by Peter Reynolds, there have been attempts to recreate Iron Age and medieval agricultural practice using tools and techniques for which there is archaeological or ethnographic evidence and, where possible, crops grown from the seed of wild descendants that have not been put through the centuries of selective breeding that now underpin modern cereal agriculture.[84] Again, to summarize this difficult and painstaking work seems cruel but it is necessary to do so. Reynolds's own experiments at Butser, using Iron Age techniques and selected crop varieties, achieved yields of between 22:1 and 27:1.[85] Critics have argued that their care for the crop, levels of manuring

[81] See n. 9 above.

[82] Bruce M. S. Campbell and David Hardy (eds), *Three Centuries of English Crop Yields, 1211–1491* (www. cropyields.ac.uk/, accessed 20 Mar. 2019); the Winchester data there was derived from Titow, *Yields*. The guess at 75 per cent coverage can be found in Campbell and Hardy, 'Data'.

[83] This summary is based on the information derivable from Bruce M. S. Campbell and David Hardy, 'Chronologies', in Campbell and Hardy, *Three centuries*. To access the raw data registration is required. Their database incorporates data from almost all previously published English medieval crop yields, including Titow, *Yields*, and P. F. Brandon, 'Cereal yields on the Sussex estates of Battle Abbey during

the later Middle Ages', *EcHR* 25 (1972), pp. 403–20. For occasional higher figures from England and elsewhere, see n. 50 above. The few Byzantine figures available for this period fall mostly between 3:1 and 5:1: see Jacques Lefort, 'The rural economy, seventh–twelfth centuries', trans. Sarah Hanbury Tenison, in Laiou, *Economic history*, I, pp. 231–310, at pp. 259–61.

[84] See e.g. Peter J. Reynolds, 'Cereal research', in Ollich *et al.*, *Experimentació*, pp. 113–21: 'The important aspect is that all these cereal types used in these trials are, in fact, unimproved stable plants as opposed to the genetically engineered plants common in the agricultural landscape today' (p. 120).

[85] Peter J. Reynolds, 'Crop yields of the prehistoric cereal types emmer and spelt: the worst option', in Patricia

and availability of manpower in relation to cultivated area must all have greatly exceeded those available in their target period, and that field rotations and the use of fallow may not have been the same either, all of which may be true.[86] Nonetheless, a French team led by Gérard Firmin working in the Val d'Aisne with prehistoric techniques also achieved yields between 5:1 and 20:1, while Reynolds himself attempted to meet these criticisms working in collaboration with a Catalan team at l'Esquerda, an archaeological site in Roda de Ter in the modern county of Girona.[87] There, despite no manuring, no hoeing or care for the crop between sowing and harvest, and despite one rainless spring that eliminated an entire spring harvest and greatly diminished the autumn one, the team's yields from high medieval crop types and techniques fell between averages per crop of 15:1 and 19:1 in a biennial rotation and 25:1 to 31:1 in a triennial rotation with legumes rather than fallow.[88]

All of this exceeds the results that would be expected from the written sources by a clear order of magnitude, and one has to ask why. One obvious answer is loss to birds: the crops at l'Esquerda were sown by an anachronistic seed drill so that known quantities of seed sown could be related to the harvest, whereas no such technology was available for the period of any of the figures so far given.[89] As Reynolds himself recorded, medieval English doggerel, Biblical parallels and his own experiments with broadcast sowing at Butser suggested that loss to birds would otherwise have been around 50 per cent of seed sown, even with children and fowlers active in bird deterrence.[90] In all of these cases, also, the growing land used had been fallow for years before the experiments and will have given of its best.[91] Another imponderable is

Note 85 continued
C. Anderson (ed.), *Préhistoire de l'agriculture: nouvelles approches expérimentales et ethnographiques* (CRA Monographie, 6, 1992), pp. 383–93, repr. in Anderson (ed.), *Prehistory of agriculture: new experimental and ethnographic approaches* (Institute of Archaeology Monographs, 40, 1999), pp. 267–75.

[86] See Devroey, 'Céréaliculture', p. 245, referring to Peter J. Reynolds, 'A study of the crop yield potential of the prehistoric cereals emmer and spelt wheats', in Devroey and J.-J. Van Mol (eds), *L'épeautre (Triticum spelta): Histoire et ethnologie* (1989), pp. 77–88. It should be noted that experiments at Butser without manuring still produced ratios of around 27:1 or more: see Reynolds, 'Cereal research', pp. 116–17. Devroey's survey ('Céréaliculture', pp. 229–41) makes out that spelt was an unrepresentative crop for the early Middle Ages, but as can be seen above, it was in the barns at Annappes; cf. Verhulst, *Economy*, pp. 61–3 and 68–9.

[87] Gérard Firmin, 'Archéologie agraire et expérimentation', in Laurent Feller *et al.* (eds), *Le village médiévale et son environnement: Études offertes à J.-M. Pesez* (2000), pp. 279–300 (*non vidi*), cit. by Devroey, *Économie*, I, p. 117 and n. 104.

[88] The experiments are described in Reynolds, 'Cereal yields', *id.*, 'Cereal research' and Immaculada Ollich,

Peter J. Reynolds and Montserrat de Rocafiguera, 'Agricultura medieval i arqueològia experimental: el projecte de l'Esquerda' [Medieval agriculture and experimental archaeology: the l'Esquerda project] in *IV Congrés d'Arqueològia Espanyola* [Fourth Congress of Spanish Archaeology] (3 vols, 1993), III, pp. 701–9, repr. in Ollich *et al.*, *Experimentació*, pp. 51–6 (pp. 53–5 of the reprint). The most complete figures available can be found in Carmen Cubero i Corpas *et al.*, 'From the granary to the field: archaeobotany and experimental archaeology at l'Esquerda (Catalonia, Spain)', *Vegetation Hist. and Archaeobotany*, 17 (2008), pp. 85–92.

[89] Reynolds, 'Cereal yields', p. 501, and *idem*, 'Cereal research', p. 114. Note that Ollich *et al.*, 'Agricultura', p. 55, say instead that sowing had been by hand into dug trenches, in which case this mitigation of the results may be excessive.

[90] Reynolds, 'Cereal yields', pp. 497–8 of the original. Ocaña, *Món agrari*, pp. 77–8 and 120, figs 13, 89 and 90 show medieval depictions of peasants driving birds from the field, from both Catalonia and England.

[91] Indeed, Ollich *et al.*, *Experimentació*, p. 185, record a steady decline in productivity of the fields over the course of their experiment despite their rotation programmes.

how far the genome of the modern crops, wild or not, matched that of the ones grown in the early Middle Ages after centuries.[92] A further unknown is the question of climate difference, one that simply cannot be entered into here, and another, specifically affecting the experiments at l'Esquerda, the choice of legumes instead of fallow may be anachronistic for our period; scholarly consensus seems to be that Carolingian practice would probably have been to leave the field fallow, which over time would have reduced its comparative fertility, although the evidence from Santa Giulia di Brescia does not necessarily conform with this.[93]

All of these modifications might bring the archaeological figures down towards the range of those from the high medieval written sources, but it is also wise to observe the sheer number of unknowns involved in the calculation even of those figures. Jan Titow, in publishing much of the data from Winchester now used in Campbell's project, had three full pages of variables to consider, which Campbell reproduces: they cannot all be repeated here but include such unknowable factors as whether grain was left over from a previous year or might have been bought in from elsewhere, whether manorial servants had been paid and if so how much, what grain might not yet have been threshed when the audit was made or even sold prior to threshing, whether poor-quality grain for brewing might have been separated already (which had been done at Annappes, as mentioned above), whether tithe had been taken (which on the Winchester estates was usually done in the field but might not have been elsewhere), and whether the same measures were used at all stages of the process. All of these decrease the apparent precision of these data considerably, but tend overall to represent them lower than the actual yield from the field. Titow's methodology for addressing this question may well have been reasonable for Winchester's records, frequently vocal about accounting practice, but this is less certain elsewhere.[94] As for the archaeological returns, Reynolds was understandably less ready to impugn his own techniques than to question the written evidence but he wrote with reason: 'There is, of course, no value in decrying these references but there is real point in questioning their exact meaning and where the calculation of yield might be in the post-harvest cycle of grain disbursement', which seems all the more relevant in the light of Titow's similar cautions.[95] What seems safest to say from all this, therefore, is that the figures

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[92] See n. 84 above. Reynolds, 'Cereal yields', p. 497, uses uncited pictorial evidence to argue for basic continuity of the plants from the ancient to modern eras.

[93] A summary of climate data resting on a reassuringly large body of evidence is Michael E. Mann *et al.*, 'Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia', *Proc. of the National Academy of Sciences*, 105 (2008), pp. 13, 252–7. On crop rotation, see n. 69 above: the data for variability in Arnoux, 'Paysage avec culture', including four- and five-field systems, extends into the area where Santa Giulia's property was held, so although the rendering of legumes on many of Santa Giulia's estates (Pasquali, 'S. Giulia', *passim*) could suggest that rotation with a vegetable crop may have been common there, we cannot say more.

[94] Titow, *Yields*, pp. 7–9, reproduced in Campbell and Hardy, 'Data'. Some of this complexity can be seen in early medieval records from Verona, whose bishop's administrators fairly clearly took renders both from the field and subsequently, presumably after threshing: see Andrea Castagnetti (ed.), 'Vescovato di Verona' [Bishopric of Verona] in Castagnetti *et al.*, *Inventari*, pp. 95–111, e. g. 101:

> … *et s*un*t tres sortes in ipso vico, quas p*ertine*t de curte Leonago: est una, quæ dat vinu*m *tercium, maiori*m*mo q*uar*to in ca*mpo, minudo mod*io q*uart*o, den*arios XL, pullos II, ovas X, in pascha den*arios III, lino mardas III, faba mod*io I, opera in prada IIII et duas carras de domnico feno trahere ad ipsa*m curte*m.

[95] Reynolds, 'Cereal yields', p. 498.

we have for high medieval agriculture, and the extremely limited Roman figures, represent not so much the productivity of the crops and the farming techniques used to raise them, but more the productivity of the régime operated by the landlord whose records we have. This should make us chary of attempting comparison between them and either the archaeological figures, which may have their own difficulties, or early medieval figures which we have derived in a different fashion.

<p style="text-align:center">VI</p>

What we need most are early medieval figures of the same sort as the high medieval ones, and these do in fact exist.[96] The very short polyptych of San Tommaso di Reggio, dating from an unknown point in the tenth century, gives unambiguous figures for grain sown and for the *exitus*, the yield from the field, at five estates, although we do not know whether tithe or any workers' wages had been taken from these renders before counting. The scribes' arithmetic was also extremely shaky. Nonetheless, this gives these figures only the same difficulties as the later English ones, and therefore it is worth recording that their average is 2.64:1, with high and low figures of 1.75:1 and 3.30:1, which is to place them somewhat below the high medieval yields but above Duby's abysmal ones for the Carolingian period and above those he recorded more contemporaneously, but erroneously, from Santa Giulia di Brescia.[97]

To the San Tommaso figures and the new minimum that can be set from our recalculations of the Annappes figures, however, can also be added a different sort of deduction from the polyptych of Santa Giulia di Brescia, which, while not direct testimony to crop yields, nevertheless gives us something like minimum operating levels for two of Santa Giulia's estates. These two estates were at Borgonato and Canelle Secco, and the latter is the more informative. There one could put 90 *modia* in the ground and the surveyors found only 51, but they also found 16 *prebendarii* and 39 tenants of various classes, and here, unusually, the compilers tell us: 'and the above-named *prebendarii* and tenants take (*tollent*) 195 *modia* of grain a year'.[98] I assume that the tenants were given grain by way of food when they were labouring on the monastery's own land, as most of them were obliged to do. This actually therefore gives us something like the operating figures which we do not have elsewhere for what was actually consumed of the harvest, and thus makes possible a hypothetical arithmetic of what should have been left. Even this involves an assumption about crop rotation, but if we thus assume that this estate ran on a three-field system, and that it therefore sowed at most 60 *modia* a year, we see that to keep the system running at full power a normal year would need to grow at the very least that 60 *modia*, for next year's crop, plus the 195 that would be given to the tenants. If it ran on a biennial rotation, they would have needed that 195 plus 45 *modia* seed. This, of course, completely omits the share of the monastery for whose benefit this estate was operating, but that cannot be reconstructed. Nonetheless, if the monastery had taken nothing,

[96] I was informed of these data by Professor Chris Wickham, to whom I owe considerable thanks.

[97] Andrea Castagnetti (ed.), 'S. Tommaso di Reggio' [Saint Thomas of Reggio], in *idem et al.*, *Inventari*,

pp. 193–8; see also Fumagalli, 'Rapporto', for which reference I am also grateful to Chris Wickham.

[98] Pasquali, 'S. Giulia', pp. 55–6, my translations.

however unlikely that may be, in order to repeat its performance the next year this estate had to produce at least 240 *modia* from 45 sown, 5.33:1, or 255 from 60, 4.25:1.

On top of this, of the monastery's render, however much it was, and of anything else that had been subtracted such as tithe or officials' renders, there apparently also remained 51 *modia*, which if they were surplus would raise the harvest figure still further, but it is not clear whether this was to provide the seed-corn, so it is best not to calculate with it. There was no such remainder at Borgonato, but perhaps there it had already been sown. Likewise incalculable, on other monasteries' estates and on some of Santa Giulia's, the monastery's own take was frequently a quarter of the crop, but since that cannot be guessed here and spurious figures are notorious for taking on a life of their own in scholarly literature – as indeed this article has demonstrated – the necessary arithmetic of hypothesis is left to the reader.[99]

The situation at Borgonato is less striking: here there was also land to sow 90 *modia*, but no remainder, and the prebendaries received only 65 *modia* annually.[100] Presumably other labour was available, which complicates our picture but does not preclude our use of these figures. To keep this estate running therefore required at least 100 *modia* from 50 on biennial rotation or 125 from 60 on triennial, respectively 2.00:1 or 2.37:1, although again the monastery's take and whatever other dues might be taken from it would not be included in this arithmetic.

These three Italian sources plus a recalculated Annappes thus give us eight early medieval crop yields figures all told, ranging from 1.75:1 to 5.10:1, in all cases minima which alterations of variables like crop rotation scheme at Santa Giulia, tithe and workers' wages at San Tommaso and the extent of the landlord's take at Annappes and Santa Giulia both, would raise upwards if we could only know their amount. Nonetheless, this means that our mean crop yield figure for the ninth and tenth centuries is actually 2.76:1, not Duby's gloomy minimum, and the actual yields in these places were necessarily higher than the figures we can give, by a varying margin that we cannot calculate.[101]

VII

These are the totality of the early medieval crop yields that I have located which can actually be demonstrated, and they bring us to some important conclusions. Firstly, the evidence for early medieval crop yields that has been employed in most of the literature hitherto has been inadequate and badly interpreted. In the case of the *Brevium exempla*, the information in the surveys cannot ever have been intended to record the estate's actual harvest. The text makes clear that the crop had already been at least partly distributed, and current understanding of

[99] Theodore V. Buttrey, 'Calculating ancient coin production: facts and fantasies', The President's Address, *Numismatic Chronicle* 153 (1993), pp. 335–51 at pp. 349–51; the influence of this article on my thinking is much larger than this citation can indicate. Professor Buttrey sadly died during the drafting of this article and I cannot now thank him in the way I would wish.

[100] Pasquali, 'S. Giulia', pp. 56–7.

[101] Averaging the figures for biennial and triennial rotation for each Brescia estate and rounding all to two decimal places, so:

(2.02 [Annappes] + ((5.33 + 4.59) / 2) [Canelle Secco] + ((2.00 + 2.37) / 2) [Borgonato] + 2.80 + 3.33 + 1.75 + 2.00 + 2.33 [all San Tommaso]) / 8.00 =

(2.02 + 4.96 + 2.19 + 2.80 + 3.33 + 1.75 + 2.00 + 2.33) / 8.00 =

22.08 / 8.00 = 2.76.

the Carolingian design for fiscal distribution of produce suggests that almost all of it might have been. What we see there is therefore the surplus that Carolingian agriculture was capable of generating above and beyond its needs, and our recalculated yield figure of 2.02:1 there is an absolute minimum for an estate that presumably ran at a considerably higher margin, the intended result of the intensified management laid down in the *Capitulare de villis*. Saint-Germain-des-Prés might have shown us something similar if its figures were usable for this purpose, but they are not.

Meanwhile, at Santa Giulia di Brescia, while the arithmetic used to obtain Duby's 1.70:1 and similar figures is unsustainable and unsalvageable, elsewhere in the text information exists from which yields, again minima that must in practice have been exceeded, of 2.00:1 or 5.10:1 can realistically be derived, while San Tommaso di Reggio contributes five more figures which mostly fall within the same range. While they hang some way below the maxima that archaeological experiment has suggested could be obtained from the luckiest of estates, presumably partly because of subtractions of the numerous kinds required to operate such an agriculture in early medieval society, these figures do thus fall within the ranges recorded, somewhat shakily, from the Roman and, more securely, from the high medieval period. It is still impossible to reason from texts such as these to definite yields, because we cannot know what part of the harvest was destined for consumption or sale elsewhere before the storage of the amount for which we have figures. Furthermore, it is important again to emphasize that a picture of the Carolingian economy based entirely on cereal yield figures would be substantially incomplete.[102] We do, however, have and have always had good reason to be sure that yield must normally have been considerably in excess of Duby's gloomy figures, which can be retained, if at all, as a minimum.

There is no reason, then, to believe that Carolingian agriculture was noticeably worse than that of the Romans or of the high Middle Ages. We can also see from the *Brevium exempla* that a developed estate structure might amass sufficient surplus to keep things going even in bad times. With that and the information on resource management from the other Italian polyptychs we can thus more solidly understand how polities of this era could continue, year on year, good or bad, to put large armies into the field, to feed and maybe even pay workmen for substantial building projects, and generally divert surplus sufficient to fuel the Carolingian Empire, the Carolingian Renaissance and their non-Frankish partners elsewhere.[103]

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[102] See n. 53 above, to which references can be added Devroey, 'Céréaliculture', pp. 243–46.

[103] Hereby, of course, hangs another large question, about the possible origins of the 'agricultural take-off' of the High Middle Ages in the Carolingian era and its causes, on which debate see most obviously *Croissance agricole*, but also now Helena Hamerow, *Early medieval settlements: the archaeology of rural communities in North-West Europe, 400–900* (2002), pp. 143–4; François Sigaut, 'L'évolution des techniques' in Miquel Barceló and Sigaut (eds), *The making of feudal agricultures?* (The Transformation of the Roman World, 14,

Leiden, 2004), pp. 1–31; Joachim Henning, 'Revolution or relapse? Technology, agriculture and early medieval archaeology in Germanic central Europe', in Giorgio Ausenda, Paolo Delogu and Chris Wickham (eds), *The Langobards before the Frankish conquest: an ethnographic perspective* (Studies in Historical Archaeoethnology, 8, 2009), pp. 149–73, to any of which cf. Matthew Innes, 'Framing the Carolingian Economy', *Journal of Agrarian Change*, 9 (2009), pp. 42–58. The findings here would tend to support those who have seen that expansion as founded in land clearance, e.g. Derville, *L'agriculture*, pp. 36–8, as opposed to technical change,

Questions may now have to be asked about where this leaves the supposed 'agricultural revolution' of the central Middle Ages and how the medieval progress narrative is in fact to be explained, but at least we must admit that presumed agricultural inadequacy in the early Middle Ages by contrast to later periods is not that explanation, that indeed there is evidence that they were not inadequate, and that we must find better ways to express and explain the differences between them and what came before and after.

Note 103 *continued*
e.g. Duby, or changing mentalities, e.g. Vito Fumagalli, 'Conquiste di nuovi spazi agricole', in *Il secolo di ferro: mito realtà del secolo X* (Settimane di Studio del Centro Italiano di Studi sull'Alto Medioevo, 38, 2 vols, Spoleto, 1990), II, pp. 615–35, but to go further would be a different article.